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Features of gravity anomaly and its geological significance of Bohai Sea, China

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Abstract

Gravity data was interpreted in Bohai Sea of China in order to study structural features and find out the distribution rules of oil and gas in this area. This paper, through data processing and synthetic interpretation of the gravity data in Bohai Sea, discusses characteristics of the gravity field and their geological significance, determines the fault system, divides structure unites and analyses the relationship between the features of local gravity anomaly and the distribution of oil and gas fields. The results show that Tanlu fault controlled the regional tectonic evolution and the boundary of the structure units of Bohai Sea in Bohai bay basin. Structurally, this area can be divided into seven units, including Huanghua sag, Chenning uplift, Bozhong sag, Jiyang sag, Liaohe sag, Yanshan fold belt and Jiaoliao uplift. In these sag, a lot of local structures and fault developed, and then many favorable traps and systems of migration and hydrocarbon reservoirs formed. There is a close relationship between the distribution of oil and gas fields and the local gravity highs. The relief areas surrounded by these petroleum generative depressions are the most favorable potential targets for the oil and gas exploration, and the intermediate zones between the depressions and the reliefs are also the significant areas in Bohai Sea.

Keywords: Bohai Sea; gravity anomaly; geological significance; structure unit; oil and gas distribution

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1. Introduction

Bohai Sea with an area about 73,000 km^2 is located in the east of Bohai bay basin [1]. Bohai Sea is an important part of Bohai bay basin, and connects with Liaohe, Dagang, Shengli and Jidong oilfield. With the oil and gas exploration work carried out over 40 years in Bohai sea, and the level of exploration increased, the features of regional geology and petroleum geology are understood more profound [2-4], and many giant oil/gas fields with hundred million tons output were discovered continuously, such as SZ36-1, QHD32-6, NB35-2, CFD11-1, CFD12-1, BZ25-1, PL9-1 and PL19-3 [5-9]. Because of the breakthrough understanding of the features of petroleum geology, these exploration results could be achieved in Bohai Sea. With these results summed up in time, the reference effect will come into being in the oil/gas exploration not only in the Bohai Sea but also in the adjacent regions.

In this paper, the features of the gravity field were studied, and the relationship between the features of local gravity anomaly and the distribution rules of oil/gas fields was analyzed, and the structural features were determined, and the structure units were divided, and the oil/gas distribution rules were discussed in Bohai sea of Bohai bay basin.

2. Features of gravity anomaly

Fig. 1 (a) is the Bouguer gravity anomaly map of the Bohai Sea. The map shows that the gravitational field is characterized with clear zoning. The Bouguer gravity anomaly displays a NE trending [10-11], so the main structure is reflected to the NE trending in Bohai Sea. From the northwest to the southeast, the features of Bouguer gravity anomaly reflect two high-value and one low-value (i.e. high-value in both sides and low-value in the middle part), including Qinhuangdao gravity high, SZ36-1 — LD27-2 — BZ22-2 — BZ25-1 gravity low and Jiaoliao gravity high.

The SZ36-1—LD27-2—BZ22-2—BZ25-1 gravity low displays a NE trending, and it is the part of the Bohai sea, Bohai bay basin. The anomaly is incomplete, and it displays open-to-west, open-to-south and open-to-northeast. In the center of the anomaly, the anomaly is relatively gentle, much local gravity high occurred, so there are many local reliefs. In the edge of the anomaly, the anomaly is relatively strong, so there are several large and deep faults.

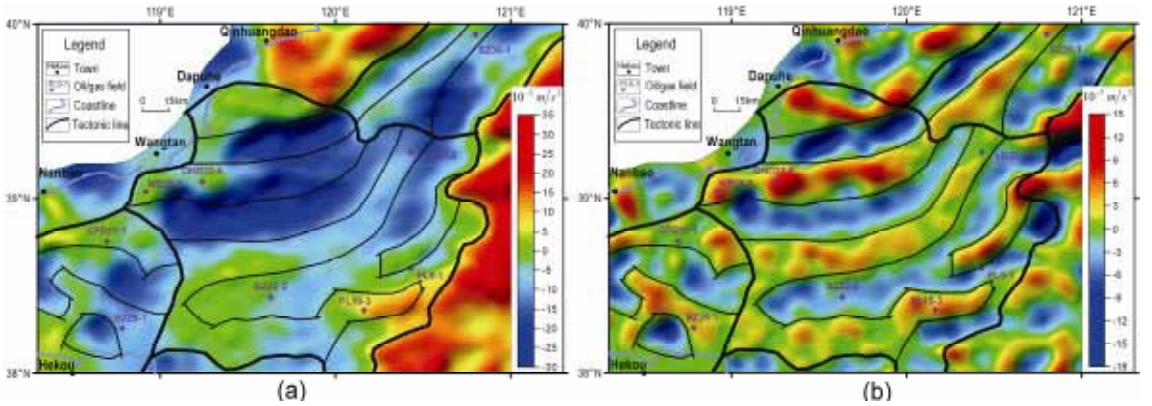

Fig. 1. (a) The fault distribution map with Bouguer anomaly in Bohai Sea; (b) The fault distribution map with local anomaly in Bohai Sea

The anomaly displays a wide range gravity low as a whole in Bohai Sea, reflecting the features of the sag. Yanshan fold belt and Jiaoliao uplift display gravity high, reflecting the features of the uplift.

Local gravity anomalies can be highlighted to reflect the gravity field caused by the local geologic bodies. If regional gravity can be suppressed and resolving power for local gravity anomaly can be improved, the local adjacent geologic bodies can be more accurately separated. In this paper, the local gravity anomaly (Fig. 1 (b)) was processed by the regularized filtering method, with fitter at geometric scale of 25km.

Fig. 1 (b) is the local gravity anomaly map of the Bohai Sea. The map shows that the gravitational field is characterized with clear zoning and local gravity high and local gravity low alternate in Bohai sea of Bohai bay basin. Local gravity anomalies can be divided into three areas by the trending, including a NE trending anomaly zone along SZ36-1 — LD27-2 — PL9-1 in the eastern part of the study area, a EW trending anomaly zone along QHD32-6 — BZ22-2 in the middle part of the study area and a NW trending anomaly zone along Nanbao — Hekou in the western part of the study area. There are a large number of local gravity highs with higher amplitude and larger range in the study area, reflecting the features of the reliefs in these sags. There are a lot of local gravity highs with lower amplitude and smaller range in the study area, reflecting the features of the reliefs in these depressions.

The vertical second derivative anomaly displays a more sensitive response to the lateral or vertical stack anomalies, so it is often used to divide the local anomaly. In this paper, the vertical second derivative anomaly (Fig. 2 (a)) was processed by Rosenbach second formula, with calculated radius of 8km. The map shows that the features of the vertical second derivative anomaly are consistent with that of the local gravity anomaly in Bohai Sea, so the local gravity anomalies reflect the local structures truly in the study area.

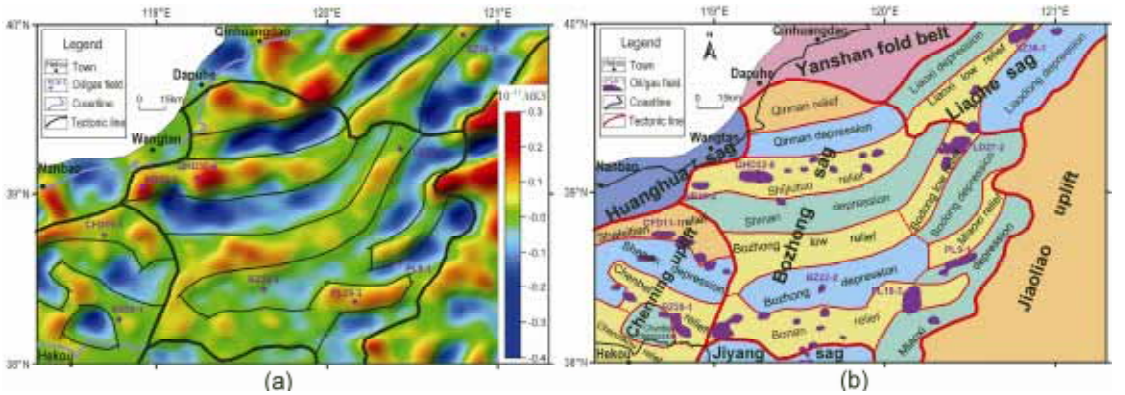

Fig. 2. (a) The fault distribution map with vertical second derivative anomaly in Bohai Sea; (b) The classification map of structure units with oil/gas fields' distribution in Bohai Sea

3. Structural features

According to the basic features of gravity anomaly, and combining with the research results of the predecessors [11-14], the study area was divided into seven structure units, including Huanghua sag, Chenning uplift, Bozhong sag, Jiyang sag, Liaohe sag, Yanshan fold belt and Jiaoliao uplift (Fig. 2 (b)).

Huanghua sag is a Mesozoic and Cenozoic rift basin on the basic of the North China platform and sub-sag of the Bohai bay basin [15]. Huanghua sag is located in the west of the study area, but only referring

to a negative structure unit — a part of Nanbao depression in Huanghua sag. Bouguer gravity anomaly and local gravity anomaly display a open-to-northwest gravity low. The gravity gradient zone occurred on the south of this sag, reflecting a connection between Nanbao depression and Shaleitian relief by faults.

Chenning uplift is located in the southwest of the study area, and is a sub-uplift of the Bohai bay basin. Bouguer gravity anomaly is relatively gentle in this uplift, reflecting a connection between Chenning uplift and its surrounding structure units by faults, but these faults are small. The local gravity anomaly map shows that NW trending gravity high and gravity low alternate in this uplift. These gravity highs and gravity lows are consistent with the sub-tectonic-units in Chenning uplift, including Shaleitian relief, Shanan depression, Chenbei relief, Chenbei depression and Chenzikou relief. Because of the effect of the surrounding faults, there are a lot of sub-faults, so the migration and reservoir systems for oil and gas are favorable. Additionally, there are rich oil/gas resources, it is favorable to form oil and gas reservoirs.

Bozhong sag is located on the west of the Tanlu fault zone and a negative independent structure unit in Bohai Sea. Bozhong sag is located in the confluence of Liaohe sag and Huanghua sag and Jiyang sag [16]. Bouguer gravity anomaly displays a wide range gravity low, and the anomaly is relatively strong in the north and east edge of this zone, reflecting a connection between Bozhong sag and Yanshan fold belt or Jiaoliao uplift by faults. These faults are large and deep, and controlled the regional structure units in the study area. The local gravity anomaly map shows that NEE or NE trending gravity high and gravity low alternate in this sag, reflecting the alternately arrangement of the depression and the relief in Bozhong sag. These gravity highs and gravity lows are consistent with the sub-tectonic-units in Bozhong sag, including five depressions — Qinnan depression, Shinan depression, Bozhong depression, Bodong depression and Miaoxi depression, and six reliefs — Qinnan relief, Shijiutuo relief, Bozhong low relief, Bonan relief, Bodong low relief and Miaoxi relief. Because of the effect of the surrounding faults, there are a lot of sub-faults in Bozhong sag, and the formation and evolution of these faults controlled the generation and migration and accumulation of the oil and gas.

Jiyang sag is located on the west of the Tanlu fault zone and a Mesozoic and Cenozoic downfaulted basin on the basic of the North China craton and a sub-sag of the Bohai bay basin [17]. Jiyang sag is located in the south of the study area, but only referring to a negative structure unit — a part of Huanghekou depression in Jiyang sag. Bouguer gravity anomaly displays an open-to-south gravity low. The gravity gradient zone occurred on the north of this sag, reflecting a connection between Huanghekou depression and Bonan relief by faults.

Liaohe sag is located on the west of the Tanlu fault zone and a downfaulted basin for rich oil and gas [18]. Liaohe sag is located in the northeast of the study area. Bouguer gravity anomaly displays an open-to-northeast gravity low. The anomaly is relatively strong in the east and west edge of this zone, reflecting a connection between Liaohe sag and Yanshan fold belt or Jiaoliao uplift by faults, and showing the piedmont fault and the Tanlu fault controlled the tectonic framework of Liaohe sag. The local gravity anomaly map shows that NE trending gravity high and gravity low alternate in this sag, reflecting the alternately arrangement of the depression and the relief in Liaohe sag. These gravity highs and gravity lows are consistent with the sub-tectonic-units in Liaohe sag, including Liaoxi depression, Liaoxi low relief and Liaodong depression. Because of the effect of the surrounding faults, there are a lot of sub-faults, so the migration and reservoir systems for oil and gas are favorable. Additionally, there are rich oil/gas resources, it is favorable to form oil and gas reservoirs.

Yanshan fold belt is located in the north of the study area and a Mesozoic fold thrust zone on the basic of the North China craton [19]. Bouguer gravity anomaly displays an open-to-north gravity high. The anomaly is relatively strong in the east and south edge of this zone, reflecting a connection between Yanshan fold belt and Bozhong sag or Liaohe sag by faults.

Jiaoliao uplift located in the east of the study area, and the Bouguer gravity anomaly displays a NNE trending open-to-east gravity high. The anomaly is relatively strong in the west edge of this uplift. The

gravity gradient is a reflection of the Tanlu fault zone, reflecting the Tanlu fault playing an important role in the regional tectonic evolution in the study area.

4. Features of the oil and gas distribution

According to the oil and gas information of the former [7-9], the distribution of the major oil and gas fields was obtained in Bohai area (Fig. 2 (b)). Fig. 2 (b) shows that CFD11-1 and CFD12-1 reservoirs are located in Shaleitian relief, and NB35-2, QHD32-6 and QHD30-1 reservoirs are located in Shijiutuo relief, and SZ36-1 reservoirs is located in Liaoxi low relief, and LD27-2 reservoirs is located in Bodong low relief, and BZ25-1 and PL19-3 reservoirs are located Bonan relief, and BZ22-2, PL9-1 and PL25-6 reservoirs are located in the fault zones between the depressions and the reliefs. Except for the large oil and gas fields, the majority of the other oil and gas fields are located in Shaleitian relief, Chenbei relief, Shijiutuo relief, Bonan relied, Liaoxi low relief and Bodong low relief, and the minority of the other oil and gas fields is located in the fault zones between the depressions and the reliefs.

Because of the effect of the surrounding faults, the sub-reliefs, the low reliefs, the nosing structures and the faults were formed in these sags and uplifts in Bohai sea of Bohai bay basin, so the migration and reservoir systems for oil and gas are favorable. Additionally, there are rich oil/gas resources, it is favorable to form oil and gas reservoirs. These reliefs and low reliefs are consistent with the gravity highs of the local gravity anomaly in Bohai area of Bohai bay basin, reflecting the stronger relativity between the distribution of oil/gas fields and the local gravity highs in this area.

5. Conclusions

The macro-distribution of the faults in the study area is consistent with that of the regional structure. Tanlu fault with NNE trending controlled the regional tectonic evolution and the boundary of the structure units in Bohai Sea.

This area can be divided into seven structure units, including Huanghua sag, Chenning uplift, Bozhong sag, Jiyang sag, Liaohe sag, Yanshan fold belt and Jiaoliao uplift. In these sag, a lot of local structures and fault developed. Because of the effect of the surrounding faults, the sub-reliefs, the low reliefs, the nosing structures and the faults were formed in these sags and uplifts in Bohai Sea. There are a lot of favorable traps, and the systems of migration and reservoir for oil and gas are favorable.

There is the close relationship between the distribution of oil and gas fields and the local gravity highs in Bohai sea of Bohai bay basin. The relief areas (i.e. local gravity highs) surrounded by these petroleum generative depressions are the most favorable potential targets for the oil and gas exploration, and the intermediate zones (i.e. the areas between the local gravity highs and the local gravity lows) between the depressions and the reledfs are also the significant areas in Bohai Sea.

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